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RESEARCH MEMORANDUM

A COMPILATION OF EXPERIMENTAL FLUTTER INFORMATION

By H. J. Cunningham and Harvey H. Brown

Langley Aeronautical Laboratory
Langley Field, Va.

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

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SUMMARY

Some salient results of much of the postwar experimental research in the United States on the flutter of simplified wing and wing-aileron models are compiled and references to the sources are given. Results of investigations by and for the National Advisory Committee for Aeronautics, the U. S. Air Force, the Department of the Navy, and the Massachusetts Institute of Technology are included. The tabulated material is grouped as follows: (1) wings without concentrated weights, (2) wings with concentrated weights, simulated engines, or fuel tanks, (3) delta and triangular wings, and (4) wings with control surfaces. Plots are included to show experimental coverage of ranges of aspect ratio, Mach number, and sweep angle for flexure-torsion flutter of simply constructed models.

INTRODUCTION

Flutter by its very nature is an exceedingly complex phenomenon, combining aerodynamic, structural, and inertial effects. In spite of commendable efforts in the theoretical field, this complexity has often forced a reliance on experimental methods, with the result that there now exists a considerable quantity of experimental flutter information.

A compilation of this experimental flutter information would perform three primary functions for the flutter analyst in industry and in research. These functions are: (1) to provide an index which should help the analyst to locate specific cases of interest, (2) to show what ranges of configurations and speeds have been covered in past tests so that duplication in future research would be avoided, and (3) to show where there is a lack of information on configurations of current interest, and thus to serve as a guide to future research.

The present compilation is limited in its scope to postwar research (with a few exceptions) done in the United States by and for the National Advisory Committee for Aeronautics, the U. S. Air Force, the Department of the Navy, and the Massachusetts Institute of Technology. This research has been done with finite-span simplified models (no two-dimensional models or complete airplanes are included). Not included are tests related to stall flutter, control-surface buzz flutter, propeller-blade and helicopter-blade flutter, and the flutter of metal coverings. A small bibliography relating to these types of flutter is provided herein. Even though the present compilation is not exhaustive, the information included should be useful and can possibly be a basis for a more comprehensive and detailed survey.

ARRANGEMENT OF MATERIAL

The material has been grouped into tables in the following order:

Table I presents data for wings without concentrated weights

Table II presents data for wings with concentrated weights, simulated engines, or fuel tanks

Table III presents data for delta and triangular wings

Table IV presents data for wings with control surfaces

Each of these tables is further subdivided to indicate the organization performing or sponsoring the tests as follows:

(a) NACA

(b) Wright Air Development Center of the U. S. Air Force

(c) Bureau of Aeronautics, Department of the Navy

(d) Massachusetts Institute of Technology

It was impracticable to include all parameters for every experiment in the present compilation. The items presented, however, include some primary geometric and elastic parameters, some flutter test results, and an indication of the source or reference where more detailed information can be found for each specific experiment. The information compiled was obtained from references 1 to 44 and from unpublished tests.

The items in the tables are arranged according to increasing sweep angle; these angles appear as subheadings within tables I, II, and IV. For any one sweep angle the arrangement is according to increasing aspect ratio. Since so many of the tests were of untapered models of uniform section, mention of any taper ratio other than 1.0 is confined to the "Remarks" column. In the column of Mach number there are included the maximum Mach number of a few wing models on rockets or bombs which did not flutter, even though such results are, in a sense, negative. The notation (max., no flutter) appears beside such quantities. For convenience the references are indicated in the tables by reference numbers, and the reference section is arranged in chronological order for each organization. Also for convenience, the test facilities are indicated in the tables by code letters, which refer to a separate listing in the "Facilities and Techniques" section.

In order to show the coverage of aspect ratio and Mach number for flexure-torsion flutter of simply constructed models, figure 1 is presented, based on the material of tables I to III, and is divided into four parts according to angle of sweepback: figure 1(a) is for sweepback of 0°, 1(b) is for sweepback of 15° to 35°, 1(c) is for sweepback of 45°, and 1(d) is for sweepback of 52.5° to 60°. The number of tests of one wing or a related series of wings of constant aspect ratio over a range of Mach number is given. Similarly, for $M = 1.3$, the number of tests of wings which are of one type but vary in aspect ratio are given.

TERMINOLOGY

The terminology which follows is presented to assist in the interpretation of column headings and the "Remarks" column in the tables.

Area, wing - The projected plan-form area, including intercepted area in a fuselage, if present.

Aspect ratio - The ratio of the square of the span to the area. For semispan models the area is twice the projected plan-form area and the span is twice the semispan.

Delta wing - A wing having a plan form similar to the Greek letter Δ, with the point foremost and the trailing edge unswept. For the wind-tunnel tests reported herein, the wing is a half-delta, clamped along the line of maximum chord.

Frequency ratio ω_h/ω_α - The ratio of frequency of the lowest frequency vibration which is primarily bending to the frequency of the lowest frequency vibration which is primarily torsion. For most cases this ratio is of the uncoupled frequencies; for unusual configurations or mass distributions, however, the frequencies are those of coupled or natural vibrations.

Flat-plate section - An airfoil section which has parallel top and bottom surfaces; the leading and trailing edges may be blunt or rounded.

Hexagonal section - An airfoil section having top and bottom surfaces that are parallel except near the leading and trailing edges, which are beveled to knife edges.

Mass parameter - The ratio of mass of a wing section of unit length (excluding any external concentrated weight) to the mass of a cylinder of "air" (or other fluid flutter medium) with unit length and specified diameter. The mass parameter for various wings is determined as follows: (1) for simple delta wings, it is based on the root or maximum chord section; (2) for tapered or nonuniform wings, it is based on the section at the three-quarter-semispan station, which section is normal to a chosen reference (or elastic) axis; and (3) for untapered wings, it is based on sections normal to the leading edge.

Reduced flutter speed $1/k$ - The reciprocal of the reduced flutter frequency k. Physically, this quantity is a reduced wave length in that it is the number of semichords of air passing over an airfoil section for each radian of oscillation. The reduced flutter speed is based on root or maximum chord for delta wings and on the chord at the three-quarter-semispan station for all other wings.

Semispan - Half the distance from wing tip to wing tip on rocket and bomb models, or the distance from the wing tip to the tunnel wall at which the wing root is supported, measured normal to the airstream direction.

Span - Twice the semispan.

Sweep angle - The complement of the angle from the plane of symmetry to a reference line. That reference line is the leading edge for delta and triangular wings and is a chosen elastic (or reference) axis for other swept wings.

Taper ratio - The ratio of the chord at wing tip to the chord at wing root.

Thickness ratio - The ratio of maximum thickness to the chord for an airfoil section in the stream direction.

Triangular wing - A wing with a taper ratio of zero, differing from a delta wing in that the angle of sweep of the trailing edge is not zero. This wing is also known as an arrowhead wing.

FACILITIES AND TECHNIQUES

A. Langley 2- by 4-foot flutter research tunnel (formerly the Langley 4.5-foot flutter research tunnel)

B. Langley supersonic flutter apparatus

C. Langley Transonic Blowdown Tunnel

D. Bomb technique of the NACA (a freely falling body with wings attached)

E. Rocket technique of the NACA (a rocket-propelled body with wings attached)

F. Wright Air Development Center 5-foot tunnel

G. Cornell Aeronautical Laboratory $8\frac{1}{2}$ by 12 foot Variable Density Tunnel

H. GALCIT 10-foot wind tunnel

I. Wing-flow method on an airplane

J. Massachusetts Institute of Technology Aero-Elastic and Structures Research Laboratory $5' \times 7\frac{1}{2}'$ wind tunnel

K. Massachusetts Institute of Technology $5' \times 7\frac{1}{2}'$ Wright Brothers Tunnel

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 19, 1953.

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TABLE I.- WINGS WITHOUT CONCENTRATED WEIGHTS

(a) NACA

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
1.52	1.52	Hexagonal 0.95% thick	0.438	1.3	10.22	64.5	1	B	26	4	
2.00	8.004	NACA 16-005	.435	.731 to .790	4.46 to 4.89	14.3 to 16.4	2	A	16	163	Tests in Freon
2.00	8.004	NACA 16-005	.533 to .534	.753 to .882	4.16 to 5.15	14.28 to 23.91	3	A	16	164	Tests in Freon
2.00	8.004	NACA 16-005	.405	.720 to .863	4.98 to 6.71	15.2 to 25.05	2	A	16	165	Tests in Freon
2.00	2.00	Hexagonal 0.9% thick	.373	1.3	17.10	179.5	1	B	26	6	
3.00	3.00	Hexagonal 1.66% thick	.250	1.3	13.00	68.4	1	B	26	2	
3.00	6.00	Modified circ. arc 5.0% thick	.606	1.3	7.71	51.7	1	B	9	G-1	
3.37	7.13	Modified circ. arc 4.74% thick	.614	1.3	9.04	53.5	1	B	9	D-1	
3.72	7.50	NACA 16-010	.64	1.3	10.03	130.0	1	B	9	B-5	
3.88	3.88	Hexagonal 1.6% thick	1.63	1.3	25.30	319.0	1	B	26	5	
3.96	6.0	Circ. arc 8% thick	.432	1.3	9.72	67.1	1	B	9	C-1	
3.96	6.0	Circ. arc 8% thick	.435	1.3	9.92	74.1	1	B	9	C-2	
4.0	1.142	NACA 65A004	.365	.81 to 1.35	4.4 to 5.3	21.7 to 36.2	23	C	30	400	Taper ratio, 0.6
4.00	24.0	NACA 16-012	1.111	.212 to .737	1.52 to 4.98	6.0 to 91.0	10	A	18	17-32-2	Balsa ribs and skin with single spar
4.00	24.0	NACA 16-012	.905	.279 to .835	1.92 to 6.49	7.7 to 101.6	9	A	18	27-38-2	Balsa ribs and skin with single spar; one test in Freon
4.0	15.996	NACA 16-005	.524	.258	1.39	5.72	1	A	16	151	Test in Freon with end plate
4.00	15.996	NACA 16-005	.537 to .564	.219 to .596	3.12 to 4.37	19.63 to 44.6	3	A	16	152	Two tests with end plate
4.0	16.0	NACA 16-005	.421	.82	2.91	13.3	1	A	17	11 A	
4.0	16.0	NACA 16-005	.703	.24	3.19	17.6	1	A	17	11 A'	
4.0	16.0	NACA 16-005	.674	.74	4.83	40.3	1	A	17	11 B'	Test in Freon
4.0	6.06	NACA 65-007	.48	1.3	10.15	64.9	1	B	9	A-1	
4.1	24.6	NACA 65-009	.537	.92	5.38	31.1	1	E	7	FR1-C	Only left wing fluttered
4.52	9.13	Circ. arc 3.0% thick	.308	1.3	19.13	267.5	1	B	9	E-1	
4.53	9.13	NACA 16-010	.583	1.3	9.98	95.3	1	B	9	B-1	
4.53	9.13	NACA 16-010	.645	1.3	10.31	108.1	1	B	9	B-2	
4.53	9.13	NACA 16-010	.633	1.3	10.20	113.1	1	B	9	B-3	
4.53	9.13	NACA 16-010	.57	1.3	10.40	113.3	1	B	9	B-4	
4.53	9.13	Double wedge 3.0% thick	.215	1.3	19.61	150.8	1	B	9	F-1	
5.00	5.00	Hexagonal 2.0% thick	.167	1.3	17.73	157.5	1	B	26	3	
5.34	21.375	NACA 65-009	.180	1.025		65.8	1	D	1	IV	
6.0	36.0	NACA 16-012	.741	.110 to .313	1.98 to 4.20	5.9 to 58.2	8	A	18	17-32-3	Balsa ribs and skin with single spar
6.0	36.0	NACA 16-012	.741	.299 to .455	1.70 to 2.74	1.4 to 12.0	7	A	18	17-32-3	Balsa ribs and skin with single spar; tests in Freon
6.0	36.0	NACA 16-012	.601	.204 to .622	2.26 to 7.99	7.6 to 97.0	7	A	18	27-38-3	Balsa ribs and skin with single spar

TABLE I.- WINGS WITHOUT CONCENTRATED WEIGHTS - Continued

(a) Continued

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
6.0	36.0	NACA 16-012	0.601	.303 to .572	1.69 to 3.46	2.3 to 17.1	7	A	18	27-38-3	Balsa ribs and skin with single spar; tests in Freon
6.0	36.0	NACA 16-012	.551	.306 to .478	1.49 to 2.52	2.6 to 14.8	5	A	18	39-42-3	Balsa ribs and skin with single spar
6.0	24.0	NACA 16-010	.162	.475	7.43	56.1	1	A	16	141	
6.0	24.0	NACA 16-010	.239	.623	3.95	12.4	1	A	16	142	Test in Freon
6.22	24.94	NACA 16-010	.22	.88		34.2	2	E	4	3 and 4	Instrumentation to indicate wing failure but not frequency information
6.84	27.375	NACA 65-009	.159	.84	14.68	77.3	1	D	5	2001	
6.84	27.375	NACA 65-009	.119	1.01 (max., no flutter)		70.0	1	D	5	2002	No flutter up to listed Mach number
6.84	27.375	NACA 65-009	.179	.895	21.68	111.0	1	D	5	3001	
6.84	27.375	NACA 65-009	.164	1.145 (max., no flutter)		74.2	1	D	5	3002	No flutter up to listed Mach number
6.84	27.375	NACA 65-009	.145	.895		100.4	1	D	1	III	
6.9	27.625	NACA 65-009	.205	.882		92.8	1	D	1	II	
7.0	14.004	NACA 16-010	.274 to .294	.498 to .804	3.42 to 7.33	11.85 to 36.7	4	A	16	132	Tests in Freon
7.0	14.004	NACA 16-010	.292	.734 to .813	4.13 to 5.70	25.3 to 34.2	2	A	16	133	Tests in Freon
7.0	14.004	NACA 16-010	.238	.355	6.42	34.8	1	A	16	134	Tested with end plate
7.0	14.004	NACA 16-010	.264	.383	5.84	33.0	1	A	16	135	
7.22	28.875	NACA 65A009	.235	1.17	10.72	32.6	1	D	11	6001	
7.22	28.875	NACA 65A009	.245	1.168 (max., no flutter)		33.1	1	D	11	6002	No flutter up to listed Mach number
7.28	29.125	NACA $65_{(09)}$A004	.135	.86 (max., no flutter)		189.7	1	D	11	5001	No flutter up to listed Mach number
7.3	29.375	NACA 65A004 to NACA 65A002	.167	.852	13.84	72.6	1	D	21	7001	Thickness ratio tapered from 4% at root to 2% at tip
7.3	29.375	NACA 65A004 to NACA 65A002	.163	.852	13.84	72.6	1	D	21	7002	Thickness ratio tapered from 4% at root to 2% at tip
7.3	29.375	NACA 65A004 to NACA 65A002	.163	1.07	16.55	77.5	1	D	21	8001	Thickness ratio tapered from 4% at root to 2% at tip
7.3	29.375	NACA 65A004 to NACA 65A002	.169	1.05	16.92	85.8	1	D	21	8002	Thickness ratio tapered from 4% at root to 2% at tip
7.34	29.375	NACA 65A009	.263	.86 (max., no flutter)		120.1	1	D	11	5002	No flutter up to listed Mach number
7.38	.683	NACA 65A004 to NACA 65A002	.158 to .169	.84 to 1.16	11.6 to 17.4	45 to 83	18	C	29	1 and 2	Thickness ratio tapered from 4% at root to 2% at tip
7.50	7.50	Hexagonal 3.2% thick	.114	1.3	21.50	133.0	1	B	26	1	
8.0	48.0	NACA 16-012	.556	.126 to .356	2.54 to 7.62	5.6 to 70.9	9	A	18	17-32-4	Balsa ribs and skin with single spar
8.0	48.0	NACA 16-012	.414	.146 to .485	2.47 to 8.37	6.9 to 110.7	9	A	18	39-42-4	Balsa ribs and skin with single spar
8.0	48.0	NACA 16-012	.454	.151 to .594	2.58 to 12.36	7.6 to 190.7	8	A	18	27-38-4	Balsa ribs and skin with single spar

TABLE I.- WINGS WITHOUT CONCENTRATED WEIGHTS - Continued

(a) Continued

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
8.0	48.0	NACA 16-012	0.454	.177 to .477	3.79 to 10.76	9.1 to 93.5	9	A	18	27-31-4	Balsa ribs and skin with single spar
8.0	48.0	NACA 16-012	.556	.208 to .325	1.94 to 3.05	1.4 to 9.1	6	A	18	17-32-4	Balsa ribs and skin with single spar; tests in Freon
8.0	48.0	NACA 16-012	.414	.216 to .394	No data	2.7 to 17.1	6	A	18	39-42-4	Balsa ribs and skin with single spar; tests in Freon
8.0	48.0	NACA 16-012	.454	.220 to .393	1.72 to 3.14	1.9 to 12.3	6	A	18	27-38-4	Balsa ribs and skin with single spar; tests in Freon
8.0	48.0	NACA 16-012	.454	.289 to .518	2.68 to 4.88	3.2 to 24.0	6	A	18	27-31-4	Balsa ribs and skin with single spar; tests in Freon
8.34	33.375	NACA 65-009	.114	.867		102	1	D	1	I	
9.0	36.0	NACA 16-010	.165	.296	6.33	51.9	1	A	16	121	
9.0	36.0	NACA 16-010	.169 to .171	.599 to .800	15.94	83.0 to 165.1	2	A	16	122	One test in Freon
9.0	36.0	NACA 16-010	.166	.379	3.43	11.08	1	A	16	123	Test in Freon
12.0	48.0	NACA 16-010	.121 to .183	.20 to .44	6.19 to 14.16	12.8 to 95.5	8	A	17	91	Tests to determine effect of center-of-gravity shift
12.0	48.0	NACA 16-010	.096	.22 to .63	2 to 8	9 to 266	39	A	8	B	21 tests in Freon
12.0	48.0	NACA 16-010	.116	.216	7.22	50.3	1	A	16	111	
12.0	48.0	NACA 16-010	.136	.233 to .429	7.79 to 16.22	42.1 to 156.5	3	A	16	112	
12.0	48.0	NACA 0010	.0884 to .0889	.346 to .786	3.54 to 7.25	19.4 to 169.3	3	A	16	114	Possible second bending-mode flutter
12.0	48.0	NACA 16-016	.157	.603 to .767	2.95 to 10.59	36.1 to 103.7	3	A	16	115	Possible second bending-mode flutter
12.0	48.0	NACA 16-006	.0703	.689	10.11	133.3	1	A	16	116	Possible second bending-mode flutter in Freon
12.0	48.0	NACA 16-010	.121 to .129	.536 to .756	19.03 to 20.41	185 to 273	4	A	16	117	
12.0	48.0	NACA 0010	.126	.264	3.70	42.5	1	A	Unpublished	CW-4A	Also tested with concentrated weight - see table II
12.0	48.0	NACA 0010	.117	.315	4.05	44.4	1	A	Unpublished	CW-4B	Also tested with concentrated weight - see table II
12.0	48.0	NACA 0010	.114	.323	3.97	45.0	1	A	Unpublished	CW-4C	Also tested with concentrated weight - see table II
12.0	48.0	NACA 0010	.120	.293	3.86	45.4	1	A	Unpublished	CW-4F	Tests with concentrated weight in table II
12.0	48.0	NACA 0010	.117	.319	3.80	44.9	1	A	Unpublished	CW-4G	Tests with concentrated weight in table II
12.4	24.8	NACA 16-010	.143	.30	7.67	36.8	1	A	17	30A	Wing failed
12.4	24.8	NACA 16-010	.136	.29	6.74	37.8	1	A	17	30B	
12.4	24.8	NACA 16-010	.161 to .179	.63 to .82	9.0 to 18.7	40.5 to 98.9	3	A	17	30C	Tests in Freon; wing failed on third test
12.4	24.8	NACA 16-010	.106 to .108	.24 to .63	3.87 to 5.36	24.2 to 75.0	4	A	17	40A	3 tests in Freon; 1 in air
12.4	24.8	NACA 16-010	.111	.23	4.08	35.5	1	A	17	40B	Wing failed
12.4	24.8	NACA 16-010	.153	.23	3.55	8.74	1	A	17	40C	Wing failed
12.4	24.8	NACA 16-010	.112	.62	5.05	79.0	1	A	17	40D	Test in Freon
12.4	24.8	NACA 16-010	.113	.40	4.15	33.1	1	A	17	50A	
12.4	24.8	NACA 16-010	.121	.52	2.61	8.66	1	A	17	50B	
13.0	26.004		.158 to .190	.262 to .763	2.29 to 7.63	10.1 to 159.2	10	A	16	118	Possible second-bending mode flutter

TABLE I.- WINGS WITHOUT CONCENTRATED WEIGHTS – Continued

(a) Continued

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 15°											
2.0	8.004	NACA 16-005	.334 to .347	.718 to .912	4.39 to 7.22	14.12 to 35.55	6	A	16	166	Tests in Freon
4.0	16.0	NACA 16-005	.4 to .417	.64 to .79	2.39 to 3.52	5.69 to 11.2	3	A	17	12	Tests in Freon
4.0	16.0	NACA 16-005	.5 to .508	.30 to .64	1.46 to 3.50	2.19 to 18.7	3	A	17	22'	Tests in Freon
11.56	24.0	NACA 16-009.66	.160	.31 to .33	2.81 to 2.95	8.7 to 8.76	3	A	17	30D	Tests in Freon
11.56	24.0	NACA 16-009.66	.105	.26	4.54	35.1	1	A	17	40A	
11.56	24.0	NACA 16-009.66	.161	.78	13.90	92.6	1	A	17	30C	Test in Freon
11.56	24.0	NACA 16-009.66	.114 to .115	.51 to .67	3.85 to 5.22	36.2 to 80.0	2	A	17	40D	Tests in Freon
11.56	24.0	NACA 16-009.66	.121	.51	2.72	8.58	1	A	17	50B	Test in Freon; model failed
12.18	25.1	NACA 16-009.66	.079	.59 to .74	9.0 to 15.7	37.2 to 81.5	2	A	17	72	Tests in Freon
12.18	25.1	Modified NACA 16-009.66	.087 to .156	.25 to .38	10.1 to 15.8	74.5 to 77.9	3	A	17	92	Tests to determine effect of center-of-gravity shift
13.0	26.0	NACA 16-010	.097	.33 to .82	6 to 20	14 to 142	27	A	8	A	18 tests in Freon
15.9	32.8	NACA 16-009.66	.067 to .068	.29 to .66	6.17 to 19.75	13.5 to 130.0	4	A	17	62	Tests in Freon
Angle of sweepback, 30°											
1.36	1.66	Hexagonal 0.824% thick	0.44	1.3	8.34	64.5	1	B	26	11	
1.69	1.96	Hexagonal 0.78% thick	.433	1.3	15.28	179.5	1	B	26	13	
2.06	2.39	Hexagonal 1.43% thick	.301	1.3	9.47	68.4	1	B	26	8	
2.38	5.66	Hexagonal 4.64% thick	.554	1.3	6.31	37.0	1	B	19	1	
2.92	6.0	Circ. arc 5.39% thick	.442	1.3	7.31	48.0	1	B	19	3	
3.00	3.46	Hexagonal 1.38% thick	.185	1.3	23.70	319.0	1	B	26	12	
3.04	3.52	Hexagonal 1.74% thick	.224	1.3	14.10	157.5	1	B	26	10	
3.99	5.98	NACA $65_{(08)}$-007.35	.378	1.3	9.73	68.0	1	B	19	2	
4.0	15.8	NACA 16-005	.355	.62	2.32	7.15	1	A	17	13	Test in Freon
4.0	15.8	NACA 16-005	.374 to .393	.42 to .81	1.68 to 3.69	3.18 to 14.9	4	A	17	23	Tests in Freon
4.7	5.43	Hexagonal 2.77% thick	.135	1.3	13.49	133.0	1	B	26	7	
5.44	6.26	Hexagonal 2.73% thick	.115	1.3	20.05	199.5	1	B	26	9	
5.64	26.1	NACA $65_{(09)}$A007.8	.259	.784	7.31	40.27	1	B	15	FR2-8L	
8.84	20.4	Modified NACA 16-008.66	.069 to .126	.23 to .41	9.90 to 14.94	73.2 to 78.0	3	A	17	93	Tests to determine effect of center-of-gravity shift
9.3	21.5	NACA 16-008.66	.136 to .137	.30	5.68 to 5.72	37.7 to 37.8	2	A	17	30B	
9.3	21.5	NACA 16-008.66	.154	.38	2.81	8.9	1	A	17	30D	
9.3	21.5	NACA 16-008.66	.103	.30		37.5	1	A	17	40A	Wing failed
9.3	21.5	NACA 16-008.66	.160 to .161	.65 to .81	7.54 to 11.52	40.0 to 81.4	3	A	17	30C	Tests in Freon
9.3	21.5	NACA 16-008.66	.113	.82	5.4	88.2	1	A	17	40D	Test in Freon
9.3	21.5	NACA 16-008.66	.121	.61	3.35	9.04	1	A	17	50B	Test in Freon
9.76	22.5	NACA 16-008.66	.066	.57 to .82	8.02 to 15.94	34.7 to 108.0	3	A	17	73	Tests in Freon
12.76	29.4	NACA 16-008.66	.054 to .063	.29 to .64	7.85 to 18.61	15.2 to 98.2	5	A	17	63	4 tests in Freon

TABLE I.- WINGS WITHOUT CONCENTRATED WEIGHTS - Continued

(a) Continued

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 34.5°											
9.28	43.7	NACA 65_1-012	0.128	.671 to .840	5.32 to 8.5	13 to 32	8	A	Unpublished	CW-2Z	Taper ratio, 0.428; also tested with concentrated weights - see table II
Angle of sweepback, 35°											
3.73	5.91	NACA $65_{(08)}$-006.96	0.383	1.3	9.98	78.1	1	B	19	4	
3.73	5.91	NACA $65_{(08)}$-006.96	.401	1.3	9.88	77.0	1	B	19	5	
3.73	5.91	NACA $65_{(08)}$-006.96	.357	1.3	9.12	68.7	1	B	19	6	
3.73	5.91	NACA $65_{(08)}$-006.96	.361	1.3	9.04	67.4	1	B	19	7	
3.73	5.91	NACA $65_{(08)}$-006.96	.414	1.3	8.79	82.5	1	B	19	8	
Angle of sweepback, 45°											
1.13	1.59	Hexagonal 0.67% thick	0.438	1.3	7.02	64.5	1	B	26	22	
1.38	1.95	Hexagonal 0.64% thick	.373	1.3	12.54	179.5	1	B	26	25	
1.50	2.12	Hexagonal 1.17% thick	.316	1.3	7.72	68.4	1	B	26	16	
1.60	1.81	Hexagonal 0.67% thick	.403	1.3	6.90	64.5	1	B	26	23	Tip modified
1.92	2.30	Hexagonal 1.17% thick	.286	1.3	6.83	68.4	1	B	26	17	Tip modified
2.00	.81	NACA 65A004	.649	.83 to 1.30	2.71 to 3.55	8.9 to 14.4	12	C	30	245	Taper ratio, 0.6
2.12	3.02	Hexagonal 1.13% thick	.222	1.3	18.21	319.0	1	B	26	24	
2.13	3.02	Hexagonal 1.41% thick	.236	1.3	11.41	157.5	1	B	26	20	
2.62	31.5	NACA $65_{(09)}$-006.4	.3	.89		26.0	1	E	3	FR1-A	Instrumentation to indicate wing failure but not frequency information; left wing failed
2.62	31.5	NACA $65_{(09)}$-006.4	.263	.65	4.49	27.0	1	E	6	FR1-B	Left and right wings fluttered under near identical conditions
2.65	3.36	Hexagonal 1.41% thick	.217	1.3	11.91	157.5	1	B	26	21	Tip modified
2.66	24.0	Flat plate 0.55 to 1.10% thick	.238	.3	5.3	25.0 (mean)	1	A	22	B_s	Taper ratio, 0.5; thickness ratio 0.55% at root, 1.10% at tip
3.00	4.24	Hexagonal 2.26% thick	.132	1.3	12.70	133.0	1	B	26	14	
3.13	26.575	NACA 16-004	.171	1.23 (max., no flutter)		62.4	1	D	24		No flutter up to listed Mach number
3.13	26.575	NACA 16-003	.161	1.23 (max., no flutter)		215.8	1	D	24		No flutter up to listed Mach number
3.50	4.95	Hexagonal 2.23% thick	.117	1.3	16.10	199.5	1	B	26	18	

TABLE I.- WINGS WITHOUT CONCENTRATED WEIGHTS - Continued

(a) Continued

Geometric and elastic parameters				Flutter test information							
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility	Reference	Model number	Remarks
Angle of sweepback, 45°											
3.77	4.95	Hexagonal 2.26% thick	0.147	1.3	13.80	133.0	1	B	26	15	Tip modified
3.88	6.01	Circ. arc 7.1% thick	.285	1.3	11.15	96.5	1	B	19	13	
3.88	6.01	Circ. arc 7.1% thick	.314	1.3	11.80	120.0	1	B	19	14	
3.93	22.26	NACA $65_{(09)}$A006.4	.410	1.44 (max., no flutter)		39.71	1	E	15	FR2-9R	No flutter up to listed Mach number
3.93	22.26	NACA $65_{(09)}$A006.4	.386	1.44 (max., no flutter)		40.85	1	E	15	FR2-9L	No flutter up to listed Mach number
4.0	1.142	NACA 65A004	.244	.80 to 1.39	4.2 to 5.3	37.1 to 61.2	19	C	30	445	Taper ratio, 0.6
4.0	16.0	NACA 16-005	.231 to .239	.56 to .81	2.56 to 5.24	7.78 to 19.8	2	A	26	14	Tests in Freon
4.0	15.4	NACA 16-005	.253 to .260	.34 to .81	1.66 to 5.70	3.64 to 30.6	5	A	17	24	Tests in Freon
4.10	6.0	NACA $65_{(10)}$-007.55	.313	1.3	12.60	120.0	1	B	19	9	
4.10	6.0	NACA $65_{(10)}$-007.55	.276	1.3	11.13	91.7	1	B	19	10	
4.10	6.0	NACA $65_{(10)}$-007.55	.270	1.3	11.28	91.7	1	B	19	11	
4.10	6.0	NACA $65_{(10)}$-007.55	.265	1.3	11.60	107	1	B	19	12	
4.25	5.61	Hexagonal 2.23% thick	.125	1.3	14.98	199.5	1	B	26	19	Tip modified
4.45	25.175	NACA $65_{(09)}$-006.4	.123	.92	11.95	125	1	D	5	4001	
4.45	25.175	NACA $65_{(09)}$-006.4	.137	.925	12.45	137	1	D	5	4002	
6.0	1.40	NACA 65A004	.091	.73 to 1.32	5.2 to 8.0	41 to 74	21	C	30	645	Taper ratio, 0.6
6.2	17.5	NACA 16-007.1	.137 to .139	.34 to .35	4.89	37.8	2	A	17	30B	
6.2	17.5	NACA 16-007.1	.160	.76	6.69	45.2	1	A	17	30C	Test in Freon
6.2	17.5	NACA 16-007.1	.159	.41	2.38	8.85	1	A	17	30D	Test in Freon
6.2	17.5	NACA 16-007.1	.114	.73	7.88	39.1	1	A	17	40D	Test in Freon; wing failed
6.2	17.5	NACA 16-007.1	.121	.68	2.28	9.45	1	A	17	50B	Test in Freon
6.50	18.4	NACA 16-007.1	.083 to .086	.35 to .85	4.02 to 13.23	14.2 to 120	3	A	17	74	Tests in Freon; wing failed on third test
7.26	20.5	NACA 16-007.1	.094 to .103	.60 to .63	2.89 to 3.88	9.15 to 9.55	3	A	17	84	Tests in Freon to study effects of tip shape
7.62	21.6	Modified NACA 16-007	.069 to .129	.17 to .21	7.68 to 8.80	68.2	3	A	17	94	Tests to determine effect of center-of-gravity shift
8.01	32.0	NACA 65A009	.151	.89	9.02	71.25	1	E	27	606L	Taper ratio, 0.54
8.01	32.0	NACA 65A009	.142	.89	9.02	78.40	1	E	27	606R	Taper ratio, 0.54
9.5	24.1	NACA 16-007.1	.064 to .067	.22 to .66	8.66 to 14.42	12.1 to 116	5	A	17	64	4 tests in Freon, 1 in air
Angle of sweepback, 52.5°											
4.0	1.142	NACA 65A004	0.17	.79 to 1.43	3.8 to 6.5	33.6 to 70.9	18	C	30	452	Taper ratio, 0.6

TABLE I.- WINGS WITHOUT CONCENTRATED WEIGHTS - Continued

(a) Concluded

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 60°											
0.66	1.31	Hexagonal 0.47% thick	0.25	1.3	5.13	64.5	1	B	26	29	
.94	1.88	Hexagonal 0.45% thick	.194	1.3	9.75	179.5	1	B	26	31	
1.00	2.00	Hexagonal 0.82% thick	.253	1.3	7.00	68.4	1	B	26	26	
1.38	2.75	Hexagonal 1.00% thick	.144	1.3	10.11	157.5	1	B	26	28	
1.50	3.0	2.00% thick	.75	1.3	7.83	74.0	1	B	19	20	
1.50	3.0	2.25% thick	.478	1.3	7.05	62.0	1	B	19	21	
1.69	3.38	Hexagonal 0.80% thick		1.3	15.00	319.0	1	B	26	30	
2.0	4.0	3.50% thick	.520	1.3	11.60	105.0	1	B	19	18	
2.0	4.0	3.25% thick	.406	1.3	9.45	97.0	1	B	19	19	
2.04	6.25	Circ. arc 4.35% thick	.557	1.3	11.50	128.0	1	B	19	16	
2.16	17.3	NACA 65A004.5	.493	1.47 (max., no flutter)		42.46	1	E	15	FR2-10L	No flutter up to listed Mach number
2.16	17.3	NACA 65A004.5	.521	1.47 (max., no flutter)		42.02	1	E	15	FR2-10R	No flutter up to listed Mach number
2.25	4.50	Hexagonal 1.58% thick	.103	1.3	15.33	199.5	1	B	26	27	
2.47	7.70	Circ. arc 4.25% thick	.500	1.3	17.25	178.0	1	B	19	15	Section centers of gravity at quarter chord
3.10	12.4	NACA 16-005	.136	.45		39.8	1	A	17	30B	Wing failed
3.1	12.4	NACA 16-005	.158	.55	1.94	9.54	1	A	17	30D	Test in Freon
3.30	13.0	NACA 16-005	.086 to .088	.54 to .56	3.31	15.8 to 16.7	2	A	17	75	Tests in Freon
3.30	13.2	Modified NACA 16-005	.112 to .215	.30 to .44	3.31 to 9.53	69.0 to 75.8	3	A	17	95'	Tests to determine effect of center-of-gravity shift
3.31	13.23	NACA 65A010	.368	1.01	3.045	29.7	1	E	15	FR2-13	Left and right wings fluttered simultaneously
3.92	6.0	Circ. arc 6.85% thick	.208	1.3	26.90	216.0	1	B	19	17	
4.0	1.142	NACA 65A004	.097	.79 to 1.37	6.5 to 8.8	77 to 124	15	C	30	460	Taper ratio, 0.6
4.0	16.0	NACA 16-005	.129	.51 to .62	3.38 to 4.30	9.10 to 14.0	2	A	17	15	Tests in Freon
4.0	16.0	NACA 16-005	.126 to .132	.41 to .79	6.70	9.36 to 34.6	2	A	17	25A 25B	Tests in Freon; models failed
4.24	17.0	NACA 16-005	.075	.67	9.74	44.1	1	A	17	65	Test in Freon
4.25	23.44	NACA 65A009	.156	1.09	18.36	59.17	1	E	27	607L	Taper ratio, 0.54
4.25	23.44	NACA 65A009	.179	1.09	18.36	59.98	1	E	27	607R	Taper ratio, 0.54
5.50	22.0	NACA 16-005	.067 to .079	.35 to .41	6.43 to 9.66	34.1 to 34.6	3	A	17	85	Tests in Freon to study effects of tip shape

TABLE I.- WINGS WITHOUT CONCENTRATED WEIGHTS - Continued

(b) Wright Air Development Center of the U. S. Air Force

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
1.15	41.4	NACA 0010	0.51					H	Unpublished		Also tested with aileron free
2.25	37.3	NACA 0009-64	.81 to 1.17	0.13 to 0.22	2.6 to 7.1	20.0 to 46.6	49	F	Unpublished		Various tip-tank configurations
2.5	10.0	NACA 65A008	.18 to .23	.66 to 1.01	12.2 to 14.7	62 to 75	11	I	35		
3.11	28.0	NACA 0008	.30	.35 to .93	14 to 30	140 to 430	56	G	32 and 33		
4.06	36.0	Clark YM-15	.25 to .30	.08 to .09	4.5 to 5.3	31.0	8	F	31		Two elastic-axis positions
7.0	21.0	NACA 23013.5	.533 to .783	<.10	.56 to 2.65	13.8 to 27.6	32	J	36		Two elastic-axis positions
11.0	33.0	NACA 23013.5	.312 to .508	<.10	1.32 to 3.5	13.9 to 27.8	27	J	36		Two elastic-axis positions
Angle of sweepback, 15°											
3.78	34.8	Clark YM-14.5	0.25 to 0.30	0.08 to 0.09	4.5 to 4.7	31.0	3	F	31		Two elastic-axis positions
Angle of sweepback, 30°											
3.04	31.2	Clark YM-13	0.25 to 0.30	0.09 to 0.10	4.0 to 4.4	31.0	3	F	31		Two elastic-axis positions
Angle of sweepback, 45°											
1.15	41.4	NACA 0010	0.21					H	Unpublished		Also tested with aileron free
1.25	7.07	NACA 65A008	.18 to .23	0.66 to 1.01	12.2 to 14.7	62 to 75	11	I	35		
1.56	19.8	NACA 0005.6	.30	.35 to .93	14 to 30	140 to 430	60	G	32 and 33		
2.03	25.5	Clark YM-10.6	.25 to .30	.10 to .11	3.5 to 3.7	31.0	4	F	31		Two elastic-axis positions
Angle of sweepback, 60°											
1.02	18.0	Clark YM-7.5	0.25 to 0.30	0.11 to 0.14	2.5 to 3.2	31.0	4	F	31		Two elastic-axis positions

TABLE I.- WINGS WITHOUT CONCENTRATED WEIGHTS - Continued

(c) Bureau of Aeronautics, Department of the Navy

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
4.0	24	NACA 0010	.558 to .591	.069 to .076	1.82 to 2.17	11.9	2	J	38	1	Two center-of-gravity positions
4.0	24	NACA 0010	.319 to .328	.093 to .117	3.40 to 4.95	11.9	2	J	38	3	Two center-of-gravity positions
7.1	30	N75	.350	<.10	5.26	18	1	J	40		Taper ratio, 0.54
7.1	30	N75	.467	<.10	6.98	18	1	J	40		Taper ratio, 0.54
8.0	72	N75	.384	<.10	2.86 to 3.56	68	2	J	37		Taper ratio, 0.5; symmetrical and antisymmetrical tests
8.0	72	N75	.39	<.10	1.44 to 3.50	13.6	7	J	39		Taper ratio, 0.5; symmetrical and antisymmetrical tests
Angle of sweepback, 25°											
4.0	24	NACA 0009	.387 to .441	.083 to .089	2.28 to 2.64	11.9	2	J	38	5	Two center-of-gravity positions
4.0	24	NACA 0009	.226 to .247	.091 to .108	3.62 to 3.79	11.9	2	J	38	6	Two center-of-gravity positions
Angle of sweepback, 35°											
3.0	18	NACA 0008.2	.386 to .454	.079	2.18 to 2.38	11.9	2	J	38	9	Two center-of-gravity positions
3.0	18	NACA 0008.2	.218 to .259	.072 to .079	3.16 to 4.07	11.9	2	J	38	10	Two center-of-gravity positions
4.0	24	NACA 0008.2	.322 to .368	.097 to .109	2.48 to 3.01	11.9	2	J	38	7	Two center-of-gravity positions
4.0	24	NACA 0008.2	.201 to .234	.081 to .102	3.94 to 5.14	11.9	2	J	38	8	Two center-of-gravity positions
5.0	30	NACA 0008.2	.283 to .306	.096 to .127	2.79 to 3.18	11.9	2	J	38	11	Two center-of-gravity positions
5.0	30	NACA 0008.2	.173 to .174	.093 to .104	3.97 to 4.93	11.9	2	J	38	12	Two center-of-gravity positions
Angle of sweepback, 45°											
4.0	24	NACA 0007.1	.248 to .282	.104 to .120	3.24 to 3.66	11.9	2	J	38	4	Two center-of-gravity positions
4.0	24	NACA 0007.1	.176 to .180	.073 to .093	4.23 to 5.32	11.9	2	J	38	2	Two center-of-gravity positions

(d) Massachusetts Institute of Technology

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
6.0	30	N75	0.399 to 0.414	<0.10	2.52 to 2.63	18.0	7	J	42		Various amounts of simulated damage; taper ratio, 0.54

TABLE II.- WINGS WITH CONCENTRATED WEIGHTS, SIMULATED ENGINES, OR TANKS

(a) NACA

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
1.42	2.13	Hexagonal 1.1% thick	0.708	1.3	21.0	51.5	1	B	Unpublished	2	Hollow tube carried at wing tip with length parallel to airstream; diameter, 1 inch; length, 7 inches
1.50	2.25	Hexagonal 2.13% thick	1.01	1.3	12.6	97.0	1	B	Unpublished	10	Do.
1.67	2.50	Hexagonal 2.13% thick	1.00	1.3	12.9	97.0	1	B	Unpublished	21	Do.
1.72	2.53	Hexagonal 2.13% thick	.821	1.3	17.8	97.0	1	B	Unpublished	13	Do.
1.77	2.66	Hexagonal 2.13% thick	.767	1.3	18.6	97.0	1	B	Unpublished	12	Do.
2.00	2.00	Hexagonal 1.15% thick	.60	1.3	55.7	215.0	1	B	Unpublished	I	Do.
2.00	2.00	Hexagonal 1.15% thick	.65	1.3	64.0	215.0	1	B	Unpublished	II	Do.
2.00	3.00	Hexagonal 2.13% thick	.641	1.3	18.2	97.0	1	B	Unpublished	14	Do.
2.25	2.25	Hexagonal 1.15% thick	.61	1.3	65.5	215.0	1	B	Unpublished	III	Do.
2.33	3.50	Hexagonal 2.13% thick	.693	1.3	26.8	97.0	1	B	Unpublished	17	Do.
2.34	3.50	Hexagonal 2.13% thick	.550	1.3	20.2	97.0	1	B	Unpublished	11	Do.
2.50	3.75	Hexagonal 2.13% thick	.59	1.3	23.5	97.0	1	B	Unpublished	20	Do.
2.58	3.87	Hexagonal 2.13% thick	.485	1.3	18.2	97.0	1	B	Unpublished	7	Do.
2.66	4.00	Hexagonal 2.13% thick	.512	1.3	22.8	97.0	1	B	Unpublished	5	Do.
2.83	4.25	Hexagonal 2.13%%thick	.529	1.3	31.4	97.0	1	B	Unpublished	16	Do.
2.96	4.44	Hexagonal 2.13% thick	.432	1.3	21.4	97.0	1	B	Unpublished	18	Do.
3.00	4.50	Hexagonal 2.13% thick	.421	1.3	21.3	97.0	1	B	Unpublished	8	Do.
3.00	4.50	Hexagonal 2.13% thick	.516	1.3	29.8	97.0	1	B	Unpublished	15	Do.
3.25	4.87	Hexagonal 2.13% thick	.414	1.3	26.0	97.0	1	B	Unpublished	19	Do.
4.94	4.94	Hexagonal 1.95% thick	.367	1.3	63.0	380.0	1	B	Unpublished	V	Do.
5.1	24.0	NACA 0010	.124 to .233	.27 to .82	3.5 to 13.0	21.2 to 66.0	54	A	Unpublished	A-1	Taper ratio, 0.571
5.1	24.0	NACA 0010	.57	.241 to .284	8.52 to 21.52	56.6 to 62.0	28	A	Unpublished	A-2	Taper ratio, 0.571; fuel-sloshing study; tank empty to full
5.84	33.6	NACA 16-005	.413 to .647	.11 to .91	2.32 to 33.0	7.4 to 438.0	106	A	Unpublished	120A	Taper ratio, 0.422
5.84	33.6	NACA 16-005	.413 to .647	.10 to .14	3.7 approx.	7.39 av.	29	A	Unpublished	120B	Taper ratio, 0.422
6.0	24.0	NACA 16-004	.2	.374 to .416	11.24 to 25.24	62.0 to 63.4	8	A	Unpublished	D-1B,2	Fuel-sloshing study; tank empty to full
9.0	36.0	Flat plate 1.125% thick	.088 to .119	.08 to .15	3.25 to 13.19	34	15	A	13	A	Weight at different spanwise positions on midchord line
9.0	36.0	Flat plate 1.125% thick	.076 to .139	.08 to .15	3.84 to 13.03	34	13	A	13	A	Weight at different spanwise positions on leading edge

TABLE II.- WINGS WITH CONCENTRATED WEIGHTS, SIMULATED ENGINES, OR TANKS - Continued

(a) Continued

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
10.0	40.0	NACA 16-004	.084 to .133	.29 to .39	5.5 to 7.1	56 to 62	22	A	12		Weight differed in mass, shape, and chordwise and spanwise position
12.0	48.0	NACA 16-004	.073 to .105	.15 to .34	3.7 to 11.0	57 to 62.7	12	A	Unpublished	D-1	Weight tested at various spanwise positions; experimental determination of flutter mode shapes made
12.0	48.0	NACA 16-010	.123 to .315	.20 to .74	.85 to 2.6	9 to 46	96	A	2		Tests with single weight differing in size and chordwise and spanwise position
12.0	48.0	NACA 0010	.129 to .213	.24 to .32	3.93 to 9.22	41.8 to 43.9	7	A	Unpublished	CW-4A	Flexibly mounted weight tested from root to tip
12.0	48.0	NACA 0010	.131 to .231	.21 to .35	3.60 to 15.55	42.1 to 43.9	10	A	Unpublished	CW-4A	Rigid weight tested from root to tip
12.0	48.0	NACA 0010	.184 to .187	.40 to .43	10.3 to 21.45	45.4 to 46.3	3	A	Unpublished	CW-4B	Flexibly mounted weight tested from 90 percent semispan to tip
12.0	48.0	NACA 0010	.182 to .196	.23 to .38	3.70 to 16.85	42.3 to 45.0	5	A	Unpublished	CW-4B	Rigid weight tested from 65% semispan to tip
12.0	48.0	NACA 0010	.191 to .225	.37 to .40	7.20 to 11.87	46.6 to 47.3	4	A	Unpublished	CW-4C	Weight tested from 35% to 65% semispan
12.0	48.0	NACA 0010	.185 to .207	.30 to .37	7.72 to 9.26	46.3 to 47.0	3	A	Unpublished	CW-4C	Flexible weight tested from 50% to 65% semispan
12.0	48.0	NACA 0010	.186 to .219	.28 to .36	3.06 to 9.63	43.4 to 46.4	4	A	Unpublished	CW-4F	Rigid weight
12.0	48.0	NACA 0010	.178 to .203	.28 to .34	4.33 to 9.34	43.1 to 43.4	4	A	Unpublished	CW-4F	Flexibly mounted weight
12.0	48.0	NACA 0010	.185 to .196	.27 to .36	4.02 to 5.34	47.0 to 48.5	4	A	Unpublished	CW-4G	Rigid weight
12.0	48.0	NACA 0010	.192	.213	4.89	44.6	1	A	Unpublished	CW-4G	Flexibly supported weight
12.0	48.0	NACA 16-006		.59 to .75		42.5 to 189	19	A	Unpublished	21	
12.1	48.0	NACA $65_{(215)}$-014	.183 to .300	.56 to .64	6.24 to 11.22	13.3 av.	5	A	Unpublished	CW-3	Taper ratio, 0.742
Angle of sweepback, 34.5°											
9.28	43.7	NACA 65_1-012	.092 to .192	.38 to .39	13.8 to 18.9	47.3 av.	3	A	Unpublished	CW-2	Taper ratio, 0.428; weights at inboard and outboard span position
9.28	43.7	NACA 65_1-012	.173 to .202	.58 to .74	8.2 to 11.2	12 to 14	5	A	Unpublished	CW-2B	Taper ratio, 0.428; both inboard and outboard weights at different chordwise positions
9.28	43.7	NACA 65_1-012	.11 to .206	.71 to .80	5.66 to 6.2	16.6	4	A	Unpublished	CW-2E	Taper ratio, 0.428; inboard of two weights at different chordwise stations
9.28	43.7	NACA 65_1-012	.175 to .181	.57 to .74	6.5 to 8.8	15.4	3	A	Unpublished	CW-2F	Taper ratio, 0.428; outboard of two weights at different chordwise stations
9.28	43.7	NACA 65_1-012	.116 to .247	.58 to .74	4.62 to 6.26	14	6	A	Unpublished	CW-2J	Taper ratio, 0.428; inboard of two weights at different chordwise stations
9.28	43.7	NACA 65_1-012	.172 to .184	.534	7.48 to 8.62	13 to 15	2	A	23		Taper ratio, 0.428

TABLE II.- WINGS WITH CONCENTRATED WEIGHTS, SIMULATED ENGINES, OR TANKS - Continued

(a) Concluded

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 45°											
4.5	25.4	Flat plate 8% thick	.061 to .144	.06 to .34	3.37 to 8.84	34	20	A	13	B	Weight at different span positions on leading edge
4.5	25.4	Flat plate 8% thick	.076 to .127	.13 to .18	6.80 to 10.25	34	15	A	13	B	Weight at different span positions on midchord line
5.68	23.3	Flat plate 8% thick	.074 to .142	.10 to .43	1.46 to 13.61	36.4 to 40.4	18	A	14	B-1	Weight at different span positions on leading edge
5.68	23.3	Flat plate 8% thick	.080 to .124	.15 to .20	6.17 to 19.95	37.8 to 38.2	15	A	14	B-1	Weight at different span positions on midchord line
5.80	24	Flat plate 8% thick	.074 to .175	.09 to .41	1.52 to 15.4	37.5 to 41.8	18	A	14	B-2	Weight at different span positions on leading edge
5.80	24	Flat plate 8% thick	.075 to .122	.15 to .19	5.90 to 19.41	34.9 to 35.6	15	A	14	B-2	Weight at different span positions on midchord line
Angle of sweepback, 60°											
2.25	18	Flat plate 0.56% thick	.082 to .148	.10 to .40	4.25 to 34.22	34.0	18	A	13	C	Weight at different spanwise positions on leading edge
2.25	18	Flat plate 0.56% thick	.077 to .134	.16 to .26	7.27 to 14.14	34.0	14	A	13	C	Weight at different spanwise positions on midchord line
3.44	23.4	Flat plate 0.56% thick	.074 to .140	.13 to .51	3.96 to 18.63	33.4 to 37.1	17	A	14	C-1	Weight at different spanwise positions on leading edge
3.44	23.4	Flat plate 0.56% thick	.072 to .121	.20 to .29	6.56 to 19.51	33.8 to 34.9	14	A	14	C-1	Weight at different spanwise positions on midchord line
3.62	24.9	Flat plate 0.56% thick	.072 to .134	.12 to .45	4.70 to 17.34	37.8 to 42.9	18	A	14	C-2	Weight at different spanwise positions on leading edge
3.62	24.9	Flat plate 0.56% thick	.068 to .111	.18 to .27	6.95 to 30.70	36.4 to 35.7	14	A	14	C-2	Weight at different spanwise positions on midchord line

[redacted]

TABLE II.- WINGS WITH CONCENTRATED WEIGHTS, SIMULATED ENGINES, OR TANKS - Continued

(b) Wright Air Development Center of the U. S. Air Force

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
5.1	72.0	NACA 0016	.72 to 1.35	.13 to .32	4.4 to 16.2	6.4	15	G	34	2 and 3	Taper ratio, 0.43; antisymmetric flutter; aileron locked and free; chordwise and spanwise locations of engine nacelles varied

(c) Bureau of Aeronautics, Department of the Navy

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
7.1	30.0	N75	0.337	<0.10	4.76	18.0	1	J	40		Taper ratio, 0.54; weight at 35% semispan
8.0	72.0	N75 11.5% thick	.384	<.10	3.23 to 11.2	13.6	95	J	37		Float at 91%; various float frequencies; taper ratio, 0.5
8.0	72.0	N75 11.5% thick		<.10	1.79 to 4.18	13.6	123	J	39		Simulated engine at 19.8% semispan; aileron included
8.0	72.0	N75 11.5% thick		<.10	1.02 to 5.30	13.6	159	J	39		Simulated engine at 33.3% span; aileron included
8.0	72.0	N75 11.5% thick		<.10	1.61 to 9.93	13.6	250	J	39		Simulated engine at 46.8% span; aileron included
8.0	72.0	N75 11.5% thick		<.10	1.85 to 5.85	13.6	97	J	37		Engines at 20% and 46% semispan; taper ratio, 0.5
8.0	72.0	N75 11.5% thick		<.10	1.93 to 11.1	13.6	28	J	37		Tip tank - with and without liquid; taper ratio, 0.5

(d) Massachusetts Institute of Technology

Geometric and elastic parameters				Flutter test information					Reference	Model number	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
Angle of sweepback, 0°											
6.0	30.0	N75	.330 to .340	<0.10	4.92 to 5.18	18.0	3	J	42		Tip tanks; various simulated damage; taper ratio, 0.54

TABLE III.- DELTA AND TRIANGULAR WINGS

(a) NACA

Geometric and elastic parameters					Flutter test information							
Sweep angle, deg	Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility	Reference	Model number	Remarks
15	7.45	6.00	Flat plate 1.03% thick		1.3	5.30	50.8	1	B	26	1	Triangular wing, trailing edge swept forward 15°
15	7.45	6.50	Flat plate 0.89% thick		1.3	10.13	67.6	1	B	26	2	Triangular wing, trailing edge swept forward 15°
15	7.45	3.25	Flat plate 0.92% thick		1.3	13.00	70.0	1	B	26	3	Triangular wing, trailing edge swept forward 15°
15	7.45	3.50	Flat plate 0.61% thick		1.3	7.72	131.0	1	B	26	4	Triangular wing, trailing edge swept forward 15°
22.5	4.82	6.00	Flat plate 0.66% thick		1.3	4.77	32.6	1	B	26	13	Triangular wing, trailing edge swept forward 22.5°
22.5	4.82	7.00	Flat plate 0.53% thick		1.3	4.63	40.3	1	B	26	14	Triangular wing, trailing edge swept forward 22.5°
22.5	4.82	3.25	Flat plate 0.61% thick		1.3	11.95	46.4	1	B	26	15	Triangular wing trailing edge swept forward 22.5°
22.5	4.82	4.00	Flat plate 0.54% thick		1.3	11.42	116.0	1	B	26	16	Triangular wing trailing edge swept forward 22.5°
30	4.74	3.25	Flat plate 0.58% thick		1.3	7.25	44.1	1	B	26	12	Triangular wing, trailing edge swept forward 15°
30	6.94	3.50	Flat plate 1.04% thick		1.3	7.70	51.4	1	B	26	5	Delta wing
30	6.94	6.50	Flat plate 0.83% thick		1.3	9.35	63.0	1	B	26	6	Delta wing
30	6.94	3.25	Flat plate 0.85% thick		1.3	9.25	64.6	1	B	26	7	Delta wing
30	6.94	3.13	Flat plate 0.61% thick		1.3	14.20	131.0	1	B	26	8	Delta wing
45	4.00	36.0	NACA 16-004	0.49	.30 to .81	1.55 to 6.2	6.8 to 165 (Mean)	48	A	25	I	Delta wing; some tests with tip cut off
45	4.00	18.0	NACA 16-004	.48	.35 to .73	2.8 to 6.8	12.1 to 87 (Mean)	21	A	25	II	Delta wing; some tests with tip cut off
45	4.00	36.0	Flat plate	.25	.22 to .80	7 to 38	12.5 to 209	29	A	25	III	Delta wing; some tests with tip cut off
45	4.00	4.75	Flat plate 0.70% thick		1.3	4.60	34.6	1	B	26	17	Delta wing
45	4.00	5.75	Flat plate 0.54% thick		1.3	5.44	41.0	1	B	26	18	Delta wing
45	4.00	3.31	Flat plate 0.47% thick		1.3	5.38	35.7	1	B	26	19	Delta wing
45	4.00	3.81	Flat plate 0.47% thick		1.3	8.45	101.0	1	B	26	20	Delta wing
45	5.46	4.75	Flat plate 0.95% thick		1.3	6.11	47.0	1	B	26	9	Triangular wing, trailing edge swept back 15°
45	5.46	5.25	Flat plate 0.81% thick		1.3	7.79	61.5	1	B	26	10	Triangular wing, trailing edge swept back 15°
45	5.46	4.25	Flat plate 0.58% thick		1.3	10.04	124.7	1	B	26	11	Triangular wing, trailing edge swept back 15°
60	2.31	22.79	NACA $65_{(06)}$-006.5	.340	.9 to 1.11	.75		1	E	20		Delta wing
60	2.31	18.71	NACA 65A003	.326	1.08	2.98	41.38 (Mean)	1	E	28		Delta wing
60	2.31	4.13	Flat plate 0.46% thick		1.3	3.36	22.7	1	B	26	21	Delta wing
60	2.31	5.88	Flat plate 0.31% thick		1.3	4.20	23.6	1	B	26	22	Delta wing
60	2.31	2.75	Flat plate 0.34% thick		1.3	4.40	25.8	1	B	26	23	Delta wing
60	2.31	3.75	Flat plate 0.28% thick		1.3	6.05	60.2	1	B	26	24	Delta wing

TABLE III.- DELTA AND TRIANGULAR WINGS - Concluded

(b) Wright Air Development Center of the U. S. Air Force

Geometric and elastic parameters					Flutter test information					Reference	Model number	Remarks
Sweep angle, deg	Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
	1.15	41.4	NACA 0010	0.32					H	Unpublished		Delta wing also tested with control surface free

(c) Bureau of Aeronautics, Department of the Navy

No information included.

(d) Massachusetts Institute of Technology

Geometric and elastic parameters					Flutter test information					Reference	Model number	Remarks
Sweep angle, deg	Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility			
77	0.915	12.0	Elliptical spanwise		0.10	.81 to 1.04	20	4	K	41		Delta wing

TABLE IV.- WINGS WITH CONTROL SURFACES

(a) NACA

No information included.

(b) Wright Air Development Center of the U. S. Air Force

Geometric and elastic parameters					Flutter test information					Reference	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of frequency ratio, $\omega_\beta/\omega_\alpha$	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility		
Angle of sweepback, 0°											
1.15	41.4	NACA 0010	0.51	.28 to 1.28					H	Unpublished	See table I(b) for locked aileron
2.25	37.3	NACA 0009-64	.23	.44 to .79	.03 to .23	1.0 to 16.3	20.0		F	Unpublished	
2.25	37.3	NACA 0009-64	.88	.56 to 1.26	.03 to .23	1.0 to 16.3	20.0		F	Unpublished	With empty tip tank
5.10	72.0	NACA 0016					6.4		G	34	
7.0	21.0	NACA 23013.5	.535 to .785	.15 to 4.68	<.10	.44 to 3.98	13.8 to 27.6	444	J	36	Two elastic-axis positions
7.0	21.0	NACA 23013.5	.347 to .462	.13 to 4.64	<.10	.98 to 3.78	13.8 to 27.6	437	J	36	Two elastic-axis positions
7.0	21.0	NACA 23013.5	.234 to .401	.17 to 3.92	<.10	1.10 to 3.65	13.8 to 27.6	438	J	36	Two elastic-axis positions
11.0	33.0	NACA 23013.5	.312 to .508	.11 to 3.53	<.10	.78 to 4.34	13.9 to 27.8	442	J	36	Two elastic-axis positions
11.0	33.0	NACA 23013.5	.224 to .325	.15 to 3.94	<.10	1.27 to 3.58	13.9 to 27.8	427	J	36	Two elastic-axis positions
11.0	33.0	NACA 23013.5	.172 to .255	.15 to 4.10	<.10	1.25 to 3.80	13.9 to 27.8	434	J	36	Two elastic-axis positions
Angle of sweepback, 45°											
1.15	41.4	NACA 0010	0.21	.33 to .92					H	Unpublished	See table I(b) for locked aileron
Angle of sweepback, 60°											
1.15	41.4	NACA 0010	0.32	.10 to 1.11					H	Unpublished	See table I(b) for locked aileron

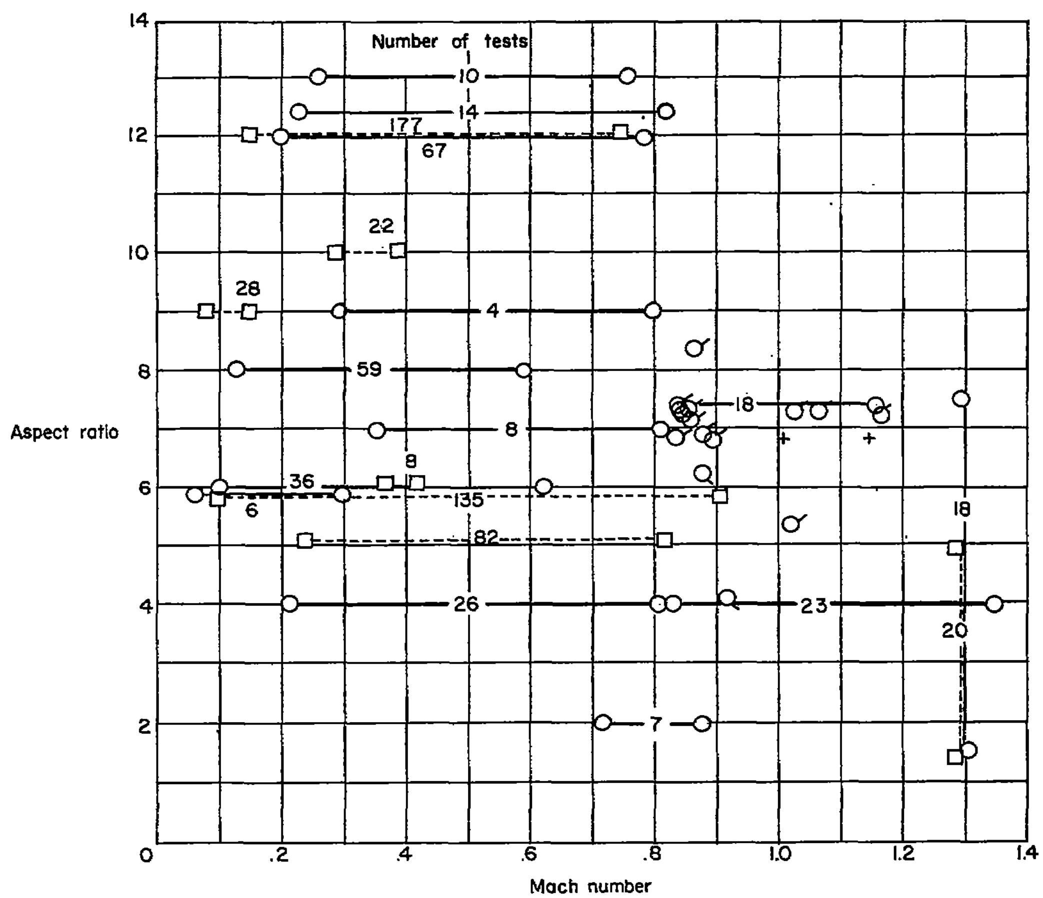
(c) Bureau of Aeronautics, Department of the Navy

Geometric and elastic parameters					Flutter test information					Reference	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of frequency ratio, $\omega_\beta/\omega_\alpha$	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility		
Angle of sweepback, 0°											
8.0	72.0	N75		.0 to 1.55	<0.10	1.45 to 3.49	13.6	70	J	39	Taper ratio, 0.5
8.0	72.0	N75		.0 to 4.33	<.10	1.98 to 8.84	13.6	180	J	39	Taper ratio, 0.5: float at 93½% span

(d) Massachusetts Institute of Technology

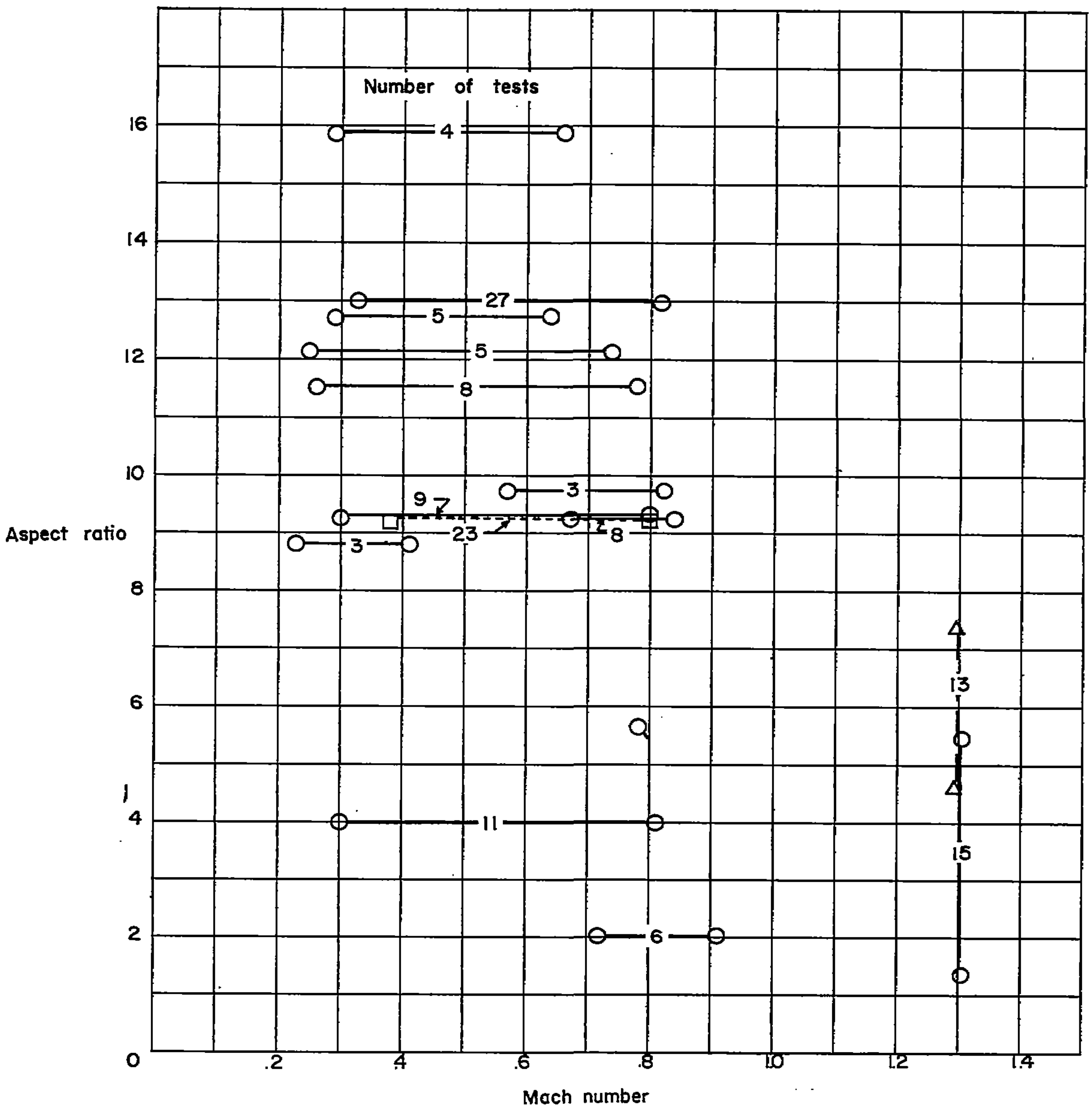
Geometric and elastic parameters					Flutter test information					Reference	Remarks
Aspect ratio	Semispan, in.	Airfoil section, including thickness ratio	Range of frequency ratio, ω_h/ω_α	Range of frequency ratio, $\omega_\beta/\omega_\alpha$	Range of Mach number, M	Range of reduced flutter speed, 1/k	Range of mass parameter	Number of tests	Test facility		
Angle of sweepback, 0°											
6.0	60.0	NACA 23015	3.66	.0 to .541	0.10	1.66 to 1.74	2.18 to 2.22	5	K	43	Wing "c"

Semispan cantilever wings in wind tunnel	Wings on rockets	Wings on bombs	
△	△		Delta and triangular
○	○	○	Swept or unswept wings without concentrated weights
□			Swept or unswept wings with concentrated weights or tubes
	+	+	Wings which did not flutter even at maximum Mach number



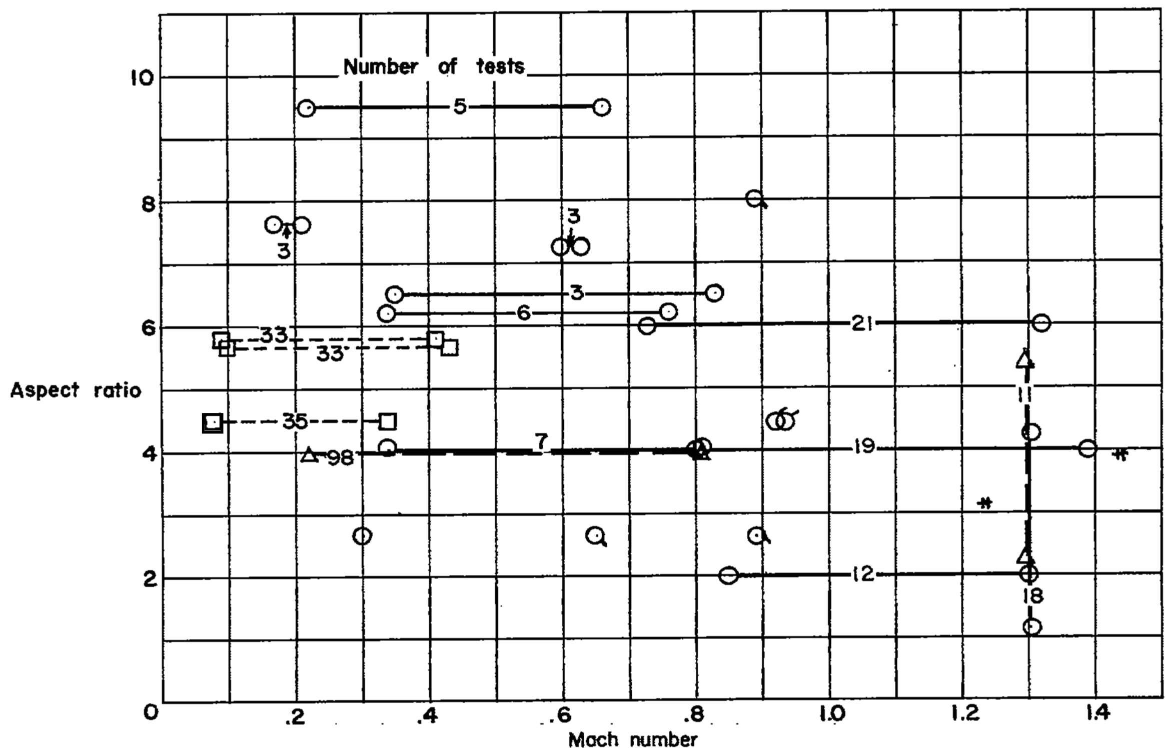
(a) 0° sweep.

Figure 1.– Coverage of ranges of aspect ratio and Mach number for bending-torsion flutter of models listed in tables I to III.



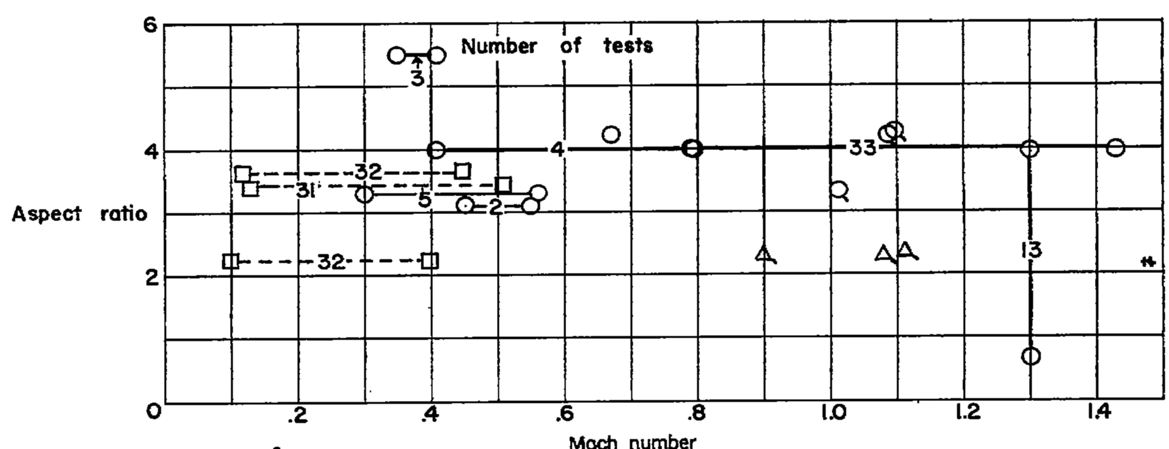
(b) 15° to 35° sweep.

Figure 1.- Continued.



(c) 45° sweep

Figure 1.- Continued.



(d) 52.5° to 60° sweep

Figure 1.- Concluded.

[redacted]